BULLETIN OF THE MILWAUKEE BUREAU OF ECONOMY AND EFFICIENCY

NO. 14

WATER WORKS EFFICIENCY

2. PRESENT CAPACITY AND FUTURE REQUIREMENTS

MILWAUKEE, WIS.
FEBRUARY 15, 1912

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BUREAU OF ECONOMY AND EFFICIENCY

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WATER WORKS EFFICIENCY
2. PRESENT CAPACITY AND FUTURE REQUIREMENTS

BY
F. E. TURNEAURE ,1866 –

PREPARED UNDER THE DIRECTION OF
B. M. RASTALL

MILWAUKEE, WIS.
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LETTER OF TRANSMISSAL

**CITY OF MILWAUKEE,
BUREAU OF ECONOMY AND EFFICIENCY.**

Milwaukee, November 1, 1911.

Mr. H. E. Briggs,
Commissioner of Public Works, Milwaukee.

Dear Sir:

We submit herewith the report of the Bureau of Economy and Efficiency on the Present Capacity and Future Requirements of the Milwaukee Water Works system, this being the second of a series of Water Works efficiency studies conducted at your request in co-operation with the City Engineer and his staff.

In such a study the chief factors requiring consideration are: a, population to be served; b, the probable rate of consumption, yearly, daily and hourly; c, the source of supply; d, the collecting and pumping capacity; and e, the distributing system.

The studies show conclusively that with the growth of the city the per capita and annual consumption will increase so that within a few years the intake, pumping and distributing capacities, which at present are only fairly adequate, will be quite inadequate to supply the city's needs.

The bureau calls attention to the recommendations relative to a new intake, greater pumping capacity, a new pumping station, additional large feeder mains, with an extension of 12 inch and 8 inch mains in the gridiron system, and an additional reservoir at an elevation on the south side.

The conclusions and recommendations are given in detail at the end of the report. The bureau wishes to acknowledge the assistance cordially rendered by the City Engineer's office. It should also be said that the recommendations relative to intake, the needed pumping capacity, and a future pumping station are all matters which are receiving careful consideration by the City Engineer's office on its own initiative.

Respectfully submitted,

(Signed) J. R. COMMONS, Director.
(Signed) B. M. RASTALL, Director.
(Signed) L. S. EVERTS, Director.

PRESENT CAPACITY AND FUTURE REQUIREMENTS

INTRODUCTION

In a study of the adequacy of the Water Works system and its future requirements the chief factors requiring consideration are: A, population to be served; B, the probable rate of consumption, yearly, daily and hourly; C, the source of supply; D, the collecting and pumping capacity; and E, the distributing system. In all of these matters estimates of future requirements must be based upon present conditions and past experience in Milwaukee, and the experience of other cities similarly situated.

THE POPULATION

Milwaukee has not grown as rapidly as some large cities, but it has had a healthy and steady growth, and its present rate is such as is likely to be maintained approximately for many years to come. The growth of population from 1870 and the rate of increase per decade are shown by the curves on Plate I. The rate of increase per decade, which was 60%, or more, from 1870 to 1890, has fallen to about 30% for the decade 1900-1910. This tendency of a decreased rate of growth is common to most large cities, and, in the case of Milwaukee, will doubtless continue to some extent in the future. After reaching a value of 25% to 30%, however, such decrease will not be rapid, and it is reasonable to expect that the future increase for two decades will not fall below 25% per decade. Estimating the rate of growth for the next two decades at 28% and 26%, respectively, gives populations of 478,000 in 1920 and 602,000 in 1930. These values are shown by the dotted extensions of the curves on Plate I. In this connection it may be said that the recent report of the Sewage Commission estimated the population at these dates at 475,000 and 585,000, respectively. Outside of the city of Milwaukee the municipal plant supplies water at the present time to a population estimated at about 25,000.

CONSUMPTION OF WATER PER CAPITA

The consumption of water per capita of the total population is, on the whole, the most convenient unit to use in comparative statistics of water consumption. Such per capita consumption depends upon many factors, such as character of population and amount of water used in manufacturing. It also depends, to an even greater degree, upon the economy with which the water is used, or the care which is taken to prevent waste. According as such waste is great or small, the consumption of water is likely to range from as high as 250 gallons per capita, daily, to 75 or 80 gallons per capita. In the prevention of such waste, the one thing which is most effective is the general use of meters, and it is shown by statistics that where meters are so used the consumption is invariably held to a moderate figure.

It should be said, however, that the use of meters does not tend to prevent loss by leakage in street mains, in service branches between main and meter, and in unused or dead services. Such loss is always a considerable item, as shown by the difference in quantity pumped and quantity metered in cities where the consumption is fully metered. Not all of such loss can be prevented, but much can be done by proper inspection to reduce it to a minimum. This subject has been fully considered in a separate report.

On Plate II are plotted curves showing the average yearly consumption per capita and the percentage of active services metered since 1880. These values are from the pump records and therefore represent the estimated pumpage rather than the consumption. They are, however, proper figures to use in connection with the estimates here considered.

It is noticeable that during the period when the use of meters was increasing rapidly, 1890-1900, the per capita consumption was materialy lessened. Since 1900, however, the services have been so fully metered that the effect of meters is no longer shown by the reduction of the consumption. If, however, the actual consumption is compared with that of other large cities, which are not so thoroughly metered, the great benefit of the meter will appear. Whereas, in Milwaukee, the consumption has remained nearly stationary at 90 to

100 gallons per capita, the consumption in many other large cities has increased to from 175 to 250 gallons per capita. Such extremely high rates of consumption are due, primarily, to absolute and useless waste of water and serve no good purpose whatever. In this respect Milwaukee is fortunate. The year 1910 is noteworthy for the large increase over the preceding year. This can doubtless be accounted for, in part, by the low rainfall for the year, but is probably due also to an increase in waste, as indicated in the bureau's report on "Water Waste."* The year 1911 will also show a large consumption, due partly to similar causes.

It seems evident from the rate of consumption for the past ten years, and a study of the consumption of other cities in which the waste of water is fairly well restricted, that the consumption, under a full meter system, is likely to increase somewhat in the future. It is estimated that, notwithstanding any reduction of waste that may be brought about by better inspection, such increase will bring the consumption to at least 120 gallons per capita in 1920, and 130 gallons per capita in 1930. This is a fairly high consumption for a fully metered system, but the large use of the public supply in Milwaukee by manufacturing industries, and the encouragement given generally by a low water rate, leads to a very liberal use of the public supply.

MAXIMUM RATE OF CONSUMPTION

In the proportioning of the collecting works, the pumping equipment, and the distributing system, the maximum rate of consumption needs to be provided for. On Plate II are plotted the ratios of the maximum daily consumption to the average daily consumption, for each year since 1890. It is seen from this diagram that the maximum daily consumption is about 40% more than the average for the year, and in 1896 was as high as 60% in excess. Again, the maximum hourly rate will be very much in excess of the average hourly rate for a day.

*If the excessive slippage in certain high service pumps, noted in the Report of Waste, existed for the entire year of 1910, the high service pumpage for that year would be reduced about 3,600,000 gallons per day, or an average of about 10 gallons per capita.

Hourly readings of pumpage were taken for a period of about a month in July and August, 1911. These results are plotted in Plates IV and V, along the lower edge of the diagrams. On July 31, for example, the maximum hourly rate was 3,200,000 gallons, while the average hourly rate for the same day was 2,270,000 gallons. The maximum hourly rate was, therefore, 141% of the average hourly rate. The same calculations for August 8 show that the maximum hourly rate was 138% of the average hourly rate.

Assuming that the maximum daily rate is 140% of the average for the year, and that the maximum hourly rate is also 140% of the average hourly rate for the day, the ratio of the maximum hourly rate to the average rate for the year will be 140 x 140, or 200%, closely. In 1911 the maximum hourly rate observed at the pumping station was 3,500,000 gallons, while the average rate for the year 1910 was 1,750,000 gallons, or exactly one-half of the maximum.

Applying this ratio to the estimated average demand for 1920 and 1930, gives a maximum rate of pumpage for those years of 115,000,000 and 157,000,000 gallons per day, respectively, for maximum hourly periods. These are approximately the figures which need to be considered in connection with the capacity of intakes, pumps and principal mains.

In addition to these rates the maximum fire demand in individual districts may need to be added, but, in view of the excellent independent fire protection of Milwaukee and the reservoir capacity, such consideration would have little influence on the larger elements of the system.

HIGH AND LOW SERVICE REQUIREMENTS

Previous to 1886 the entire city was served from what is now called the low service system. In 1886 the High Service station was built and the more elevated portions of the city to the west and north were supplied by repumping from a reservoir located on the low pressure system. In 1909 a 12,000,000 gallon pump for the high service system was installed at the North Point Pumping station to pump direct into the high pressure system. A duplicate of this pump was installed at

the same station in 1910. The total rated capacity of the pumps at the high service station itself is 25,000,000 gallons per day. The total rated capacity in the North Point station for the low pressure system is 86,000,000 gallons per day, including the two old compound beam engines of 16,000,000 gallons capacity, which are not operated. If we assign a capacity of 15,000,000 gallons to supply the reservoir for the pumps at the high service station, it leaves 71,000,000 gallons capacity for the low service proper, or 55,000,000 gallons, if the two old pumps are excluded.

The pressure maintained at the pumping station in the low pressure system averages about 68 pounds, measured from datum, and that in the high pressure system at the North Point station is about 97 pounds, measured from the same datum.

The low service district consists in the main of the following wards: 1, 2, 3, 4, 5, 7, 8, 11, 12, 14, 17, 18 and 23. This includes nearly all of the older part of the city and most of the manufacturing district. South of the Menomonee river it includes all of the city with the exception of a part of the Eleventh and Twenty-third wards. The high service district includes the northern and western quarters of the city, and, generally speaking, all of the territory above an elevation of from 80 to 90 feet above datum.

South of the river the low service district is supplied by the following mains crossing the rivers: across the Menomonee, a 16-inch and a 20-inch; across the Milwaukee, a 30-inch and a 36-inch. The low service district on the west side is supplied by mains crossing the Milwaukee river, as follows: a 36-inch at Knapp street, and a 30-inch at North avenue. The entire high service district west and south is supplied by one 36-inch main at Bradford street, so far as the supply from the North Point station is concerned.

In a study of the future requirements of the water works, the future development of the two districts is an important factor. From the statistics of the population by wards, it is possible to estimate the growth of the population of the two districts. Such growth is shown on Plate III together with the total and the per capita consumption for the two areas.

It is of interest to note that the present per capita consumption of the low service district is about 140 gallons, while that of the high service district is about 80 gallons. The difference is due apparently to the fact that most of the use for manufacturing purposes is on the low service. It is also noteworthy that for the past decade the relative increase in use of water has been much more pronounced in the high service district than in the low service district.

Considering future extensions into outlying districts it will be seen, from an inspection of the contour map of the city, that only a very small proportion of such new area can be supplied by the low service system. Taking an elevation of 80 feet as denoting the line of separation, it is found that on the south side the extensions have already reached this limit in the new area north of Oklahoma avenue and west of First avenue. Further extensions in this district must be on the high service system. The low service may still be extended a few blocks south of Humboldt Park and along the lake shore. To the west and north all future extensions will need to be on the high service except in a very narrow strip east of the Milwaukee River.

It is seen, therefore, that nearly all the future growth of the city represented by additional territory will be on the high service. The growth of population in the low service area will be very little outside of the area now in that sytem, and an examination of the population, recorded by wards, shows that such growth will be confined almost entirely to the Eleventh, Fourteenth, Seventeenth and Eighteenth wards. The increase in use for manufacturing purposes will be divided between the two services, but the amount used in the high service district will be of increasing importance in the future.

A study of the daily and hourly pumpage during a part of the dry period of 1911 shows that the variations in demand of the high service are greater at such seasons than is the case for the low service, due obviously to the character of the demand.

Considering all the factors, it is estimated that by the year 1920 the maximum rate of demand from the high pressure service will nearly equal that from the low service, and that in

another decade it will considerably exceed it. It is, therefore, probable that by 1920 the actual maximum hourly consumption in the high and low level districts will be equal to a rate of about 60,000,000 gallons per day in each district. By 1930 the demand will be 75,000,000 to 90,000,000 gallons, with the probability that the greater quantity will be in the high pressure area.

SOURCE OF SUPPLY

The quality of water obtained from Lake Michigan has, on the whole, been satisfactory since the construction of the long intake. Recently, some sewage contamination has occurred, and a continuation of the present method of sewage disposal would very soon unquestionably cause serious pollution. The active steps which the city is taking towards an adequate system of sewage disposal gives assurance that the question of contamination of the lake supply will be settled, and that this source may be continued as a source of supply for many years to come without the use of any very expensive or elaborate purification process. For industrial purposes the water is very satisfactory, and if pollution by sewage is prevented, the quality of water leaves little to be desired.

THE INTAKE

The present intake was put into operation in 1895. It consists of a 7½-foot brick lined tunnel 3,200 feet long, from the terminus of which the intake is extended by means of two lines of cast iron pipe five feet in diameter and 5,000 feet long. The depth of water at the intake is about sixty feet.

As to capacity, the amount of water which can be obtained through this intake depends upon the extent to which the water level at the land end of the tunnel can be lowered with convenience and economy. The reduction of the water level at this point, below the level of the lake, determines the pressure head available to overcome the friction loss in the length of the intake. The maximum hourly pumpage has been at the rate of about 84,000,000 gallons per day, or about 131 cubic feet per second. In the 7½-foot tunnel this would require a velocity of 3.0 feet per second, and in the cast iron pipes a velocity of

3.4 feet per second. An estimate of the loss of pressure due to friction at these velocities is about 6.0 feet. The actually observed drop of the level in the pump well has been about 6.5 feet. With the present arrangement of pump well and suction pipes the level can be reduced only about two feet further, which will increase the flow about 15 per cent, or to about 96,000,000 gallons per day. It is therefore seen that without the rearrangement of the suction well or the adoption of some special means to increase the available head the present intake will reach its capacity within a very few years.

While it would be possible to increase the capacity by suitable pumping arrangements, other considerations besides the question of frictional head are important. The present intake is not free from risk of accident. At the present time a very considerable amount of sand is constantly being drawn through the intake. The cause of this infiltration of sand has not been determined, but its continual presence indicates that it does not enter at the open end of the intake, but at some intermediate point. Whether it enters through open joints in the cast-iron pipe, or otherwise, is not known. This is a matter which should be investigated without delay. While no serious defect is likely to be discovered, yet it must be recognized that any failure of the intake would be exceedingly serious, involving as it would the use of water from the crib or from a point near the shore for a considerable length of time*.

From the standpoints of absolute safety and of future economy, a second intake should be constructed at an early

*Since this report was written the City Engineer has made an examination of the material deposited at the bottom of the 10-foot vertical shaft connecting the lake intake with the land tunnel. The material deposited at this point is found to consist of very fine sand and clay, and to contain no coarse sand or gravel. Inasmuch as the vertical shaft has a cross-section about double that of the lake tunnel, the velocity of water in the shaft would be about half that in the tunnel itself. These conditions are such that if any coarse material were conveyed through the lake tunnel, the coarser particles thereof would be deposited at the bottom of the shaft by reason of the great reduction in velocity of the water at that point. The fact that no such coarse material was found is conclusive evidence that the sand and gravel found in the pumps do not come from the tunnel proper, but from some leak in the land tunnel or in the pump wells themselves.

date. The location of such intake might well be somewhat further to the north than the present one, so as to secure the advantage of the out-jutting shore line in Lake Park. At the shore end such intake should connect by tunnel to the present pumping station, as well as to any additional pumping station which may be constructed in the vicinity.

PUMPING CAPACITY

As already noted, the total available pumping capacity at present is about 71,000,000 gallons per day for low service exclusively (assigning 15,000,000 capacity to supply the reservoir), and 49,000,000 gallons per day for high service. Of the high service capacity 25,000,000 gallons is represented by the pumps at the High Service Pumping station, and 24,000,000 capacity by the two new pumps at the North Point station. This total pumping capacity would, however, be available only by drawing upon the reservoir at a rate of 10,000,000 gallons per day.

During the present year (1911) the maximum hourly rate for the low service has been at least 55,000,000 gallons per day, and the high service about 32,000,000 to 35,000,000 gallons per day. Compared with the total available capacities the margin is about 15,000,000 gallons in each case, or about the capacity of one of the larger units.

In addition to the demand here considered, a further allowance is necessary for large fires, which is most likely to occur in very dry seasons when the consumption for other purposes is high. While the special fire system furnishes protection for a large part of the business and manufacturing district, it does not much affect the demand in the high service area. For such demands a further provision of not less than 10,000,000 gallons per day capacity, in each sytem, is necessary.

From these estimates it is evident that there exists at the present time very little margin over absolute necessities, leaving nothing for future growth. Considering present and future requirements, there should be provided at once an additional large unit for the low service in place of the two old pumps, and, within the next decade, probably two such units will be needed.

If the high service station be abandoned, as hereinafter suggested, and all high service pumpage done direct at the low level, then a part of the low service equipment will be released for low service duty proper, thus reducing the requirements for low service pumps by one unit. For the high service two 12,000,000 gallon units have recently been installed, which places the system as to capacity in a fair condition. With the slippage already referred to reduced, the margin in this system is at least 15,000,000 gallons. Within the next decade, however, an increase of two more units of 12,000,000 to 15,000,000 gallons each will be needed.

The present building at North Point is so arranged that, by the removal of the old pumps, it will accommodate two additional pumps, both of which will be needed within about five years. Any further increase will require an extension of the building or the construction of another pumping station.

ADDITIONAL PUMPING STATION

The concentration of all the pumping machinery in a single building has both advantages and disadvantages. For economical operation of pumps and boilers it is advantageous to concentrate machinery, but such an arrangement is disadvantageous by reason of the greater risk involved from possible accidents to pumps and boilers.

So far as the distributing sytem is concerned, it is advantageous to have pumping stations placed at more than a single point in the system, for thereby the pressure is maintained more nearly uniform and the size of the distributing mains need not be so large. If the quality of the water were satisfactory, a very good arrangement for Milwaukee would be to locate a second pumping station on the south side. This, however, cannot be done under the circumstances. Another method of accomplishing this object is to carry the water by tunnel to some interior point in the city where the ground is at sufficiently low elevation to permit pumps to draw water direct from the tunnel. Another method, also, of equalizing pressure is the establishment of one or more reservoirs at remote points in the system.

Concerning the relative needs of the two services in Milwaukee, and all the elements mentioned above, it would appear advantageous to locate a second pumping station on the Milwaukee river in the neighborhood of Locust street. This station would be connected by tunnel to both old and new intakes and would contain pumps for both high and low service, but would provide mainly for high service duty. By this arrangement a safe and adequate crossing of the river is provided, once for all, and the pumping station brought as closely as practicable to the district to be served. Such station would also have the advantage of track facilities for the handling of fuel and ashes, thus saving a considerable sum on haulage.

Such a station should probably be planned for future expansion to take care of all the growth of the city for many years to come, leaving the present station at its present size. This arrangement, while it would separate the operation, would give increased safety and would equalize to some extent the pressure.

THE HIGH SERVICE STATION

Under present conditions the high service station should be maintained as a matter of safety and for use during periods of maximum consumption. If, however, a second large station be constructed, as above explained, the entire high service pumping could be more economically done at that station and at the present station at North Point. In that case, the separate High Service station might well be abandoned with resulting economy. As now operated, the pumping at that station is relatively expensive.

THE RIVER CROSSINGS

Because of their large size and small number, the river crossings constitute a very important element of the system which demands special consideration.

Velocities of flow in the several mains have been determined by pitometer measurement as follows:

VELOCITY OF FLOW IN MAINS AT RIVER CROSSINGS

Location.	Size of Main	Date of Test	Hour of Test	Direction of Flow	Av. Velocity, Ft. Per Sec.	Total Pumpage at N. Point Station for Day
Bradford St. & Milwaukee River...	36"	6-12-11	3 P. M.	West	3.5	52,205,540
Knapp St. and Milwaukee River...	36"	8-31-11	3 P. M.	West	2.1	48,598,580
Third St. & Menomonee River......	20"	9-1-11	2 P. M.	South	0.5	51,366,690
Milwaukee St. & Milwaukee River	30"	9-21-11	11 A. M.	South	0.5	46,554,180
E. Water St. & Milwaukee River	36"	9-23-11	10 A. M.	South	3.5	47,682,280
E. Water St. & Milwaukee River	36"	9-23-11	5 P. M.	South	2.2	47,682,280
Muskego Ave. & N. Meno'onee Canal	16"	9-23-11	2 P. M.	South	1.2	47,682,280
North Ave. & Milwaukee River...	30"	9-28-11	3 P. M.	West	4.6	47,900,220
Becher St. & Kinnickinnic River..	16"	9-29-11	3 P. M.	East	2.3	47,900,220

The 36-inch main in Bradford street broke on September 3, and from that time until December 4 the entire high service demand, except for the small district east of the river, was supplied from the High Service Pumping station, thus throwing extra duty on the 30-inch main at North avenue, supplying the reservoir. This accounts, in large part, for the high velocity of 4.6 feet per second observed on the date of the test.

The low service west of the Milwaukee river and north of the Menomonee is supplied by a 30-inch main on North avenue running to the reservoir, and a 36-inch main at Knapp street. The reservoir also supplies water to the high service pumping station, and some part of the supply to this district also crosses

the Menomonee to the south. During periods of maximum pumping at the High Service station, such as occurred especially after the breakage of the 36-inch high pressure main at Bradford street, the velocity and friction loss in the 30-inch main at North avenue are excessive. Considering the size and low elevation of the district, the availability of the reservoir and the extent of the fire protection system, the provisions for this district appear to be adequate, if, as contemplated, most of the high service pumping is done at the North Point station.

The large district south of the river is supplied by a 36-inch and a 30-inch main across the Milwaukee river, and a 20-inch and a 16-inch main across the Menomonee. Estimating the demand in this district from the population by wards, it is probable that during the past year the rate of consumption reached 20,000,000 to 23,000,000 gallons per day. The four pipes above mentioned are closely equivalent to two 36-inch pipes, or a single 48-inch pipe, as far as friction loss is concerned; and the loss of head for a flow of 23,000,000 gallons per day amounts to about 0.7 feet per 1,000, with a velocity in the 36-inch pipe of about 2.5 feet per second. The tests quoted in the table show a velocity of 3.5 feet per second in the 36-inch pipe, which gives a loss of head of 1.2 feet per 1,000 feet. Considering the low pressures already existing in this district and its remoteness from the pumping station and reservoir, it is important that the velocities be kept low by providing ample capacity in the principal mains. The existing provisions are only reasonably adequate. The rapid growth of this district will require very soon the construction of an additional main across the river. It will be very advantageous if the next large main be built across the Milwaukee river to the west side, and thence across the Menomonee to join the south district at a point as far west as practicable.

The high service system west of the river is supplied from the North Point station through a single 36-inch main. The breakage of this main during the present year has thrown this entire duty upon the high service station, and if such breakage had occurred previous to the hot dry period of July and August, the entire plant, including the two old beam engines,

would have been drawn upon to its full capacity to supply the actual demand. This condition shows the importance of having at least two mains for such important service. An additional main (36-inch or 48-inch) should be constructed at once, from the North Point pumping station to feed into the high service district, preferably several blocks to the north of the present main, but also cross-connected thereto. Such a main is needed not only in case of breakage, but also to furnish better capacity for the ordinary maximum pumpage. The observed velocity of 3.5 feet per second in the Bradford street main is high, and when both the high service pumps at North Point are in full operation it is noted that the loss of pressure from this station to the high service district is about 10 pounds. South of the Menomonee, the high service district is now supplied by a 30-inch main, which is ample for the present, but larger connecting sub-mains are still needed to make this main fully effective.

THE DISTRIBUTION SYSTEM

The distribution system should be of such size and arrangement as to furnish adequate pressure for ordinary consumption and ample water for fire-engine service at times of fires. During the past two years there have been many complaints of inadequate pressure, especially in the extreme western edge of the city and in some of the low service territory in the southwest section. To better these conditions a number of large mains have been built or are nearing completion, which will greatly improve the system. The most important of these mains is the 36-inch main crossing through the east side district, thence across the Milwaukee river to East Water street, and thence extending southward and westward.

Another very important main feeder is the 30-inch main in the high service system on the west side, extending to National avenue. Other large mains on the south side recently completed will also assist greatly in increasing pressure in this district.

During a portion of the months of July and August, 1911, self-recording gages were temporarily installed at several points of the sytem, and records of pressures obtained therefrom for several consecutive days. The details of these records are given

in Plates IV and V. The following table gives the more important data from these observations:

TABLE OF PRESSURE RECORDS

<table>
<tr><th></th><th>No.</th><th>Place of Observation.</th><th>Elev. Above Datum, Ft.</th><th>Normal Static Pressure, Lbs.</th><th>Minimum Pressure, Lbs.</th><th>Max. Loss of Head, Lbs.</th><th>Distance from N. Point Station, Ft.</th><th>Av. Loss of Head Per 1,000 Ft., Lbs.</th></tr>
<tr><td rowspan="4">Low Service.</td><td>1</td><td>11th Ave. and Park..</td><td>12</td><td>63</td><td>49</td><td>16</td><td>26,000</td><td>0.6</td></tr>
<tr><td>2</td><td>8th Ave. and Mitchell.</td><td>68</td><td>38</td><td>26</td><td>13</td><td>30,000</td><td>0.4</td></tr>
<tr><td>3</td><td>21st and Scott........</td><td>70</td><td>37</td><td>13</td><td>24</td><td>32,000</td><td>0.7</td></tr>
<tr><td>4</td><td>Park and Bartlett....</td><td>75</td><td>35</td><td>31</td><td>4</td><td>6,000</td><td>0.7</td></tr>
<tr><td rowspan="10">High Service.</td><td>5</td><td>11th and Galena......</td><td>96</td><td>55</td><td>42</td><td>11</td><td>15,000</td><td>0.7</td></tr>
<tr><td>6</td><td>Third and Auer......</td><td>136</td><td>38</td><td>20</td><td>19</td><td>20,000</td><td>1.0</td></tr>
<tr><td>7</td><td>27th and Center......</td><td>93</td><td>57</td><td>47</td><td>7</td><td>19,000</td><td>0.4</td></tr>
<tr><td>8</td><td>24th and Auer.......</td><td>115</td><td>47</td><td>40</td><td>15</td><td>22,000</td><td>0.7</td></tr>
<tr><td>9</td><td>31st and Lloyd.......</td><td>113</td><td>48</td><td rowspan="2">25*</td><td rowspan="2">23*</td><td>20,000</td><td>1.2</td></tr>
<tr><td>10</td><td>23d and State........</td><td>110</td><td>49</td><td>23,000</td><td>1.0</td></tr>
<tr><td>11</td><td>Lisbon and North Ave.</td><td>149</td><td>32</td><td>8</td><td>24</td><td>25,000</td><td>1.0</td></tr>
<tr><td>12</td><td>30th and Clybourn....</td><td>85</td><td>60</td><td>45</td><td>12</td><td>28,000</td><td>0.4</td></tr>
<tr><td>13</td><td>41st and National Ave.</td><td>69</td><td>67</td><td>48</td><td>21</td><td>39,000</td><td>0.5</td></tr>
<tr><td>14</td><td>26th and Scott.......</td><td>91</td><td>57</td><td>46</td><td>13</td><td>44,000</td><td>0.3</td></tr>
</table>

*Average of the two stations.

It is seen that at the places of observation the lowest static pressure was 35 pounds in the low service system and 32 pounds in the high service system, the respective points being at elevations of 75 feet and 149 feet above datum. The lowest pressures observed were about 13 pounds at Station No. 3 in the low

service district (Twenty-first avenue and Scott street), and about 8 pounds at Station No. 11 (Lisbon and North avenues) in the high service district. Very low pressures (about 18 pounds) were also observed at No. 13 (Forty-first and National avenues) previous to the installation of the 30-inch high pressure main, but after this main was put into service the lowest pressure recorded at that point was about 48 pounds.

The friction loss from the pumping station to the points of observation amounted, in some cases, to from 20 to 24 pounds, and over 1 foot per 1,000 feet of distance from the North Point pumping station. In the table the maximum loss of head frequently occurred when the pressure at the pumping station was somewhat above normal, so that the figures for maximum loss of head are, in some cases, greater than the difference between the so-called normal pressure and the minimum pressure.

Many complaints have been made of unsatisfactory pressures in the neighborhood of Station No. 11 and also No. 3, and although some improvement was brought about during the past year by the construction of large mains, the observations here given, which were made after the mains were placed in service, show unsatisfactory conditions still existing.

Generally speaking, a pressure of less than 20 pounds is likely to be unsatisfactory in the residence district, where most of the stations were located; and wherever the use of four- or five-story business and apartment houses develops, a minimum pressure of 30 pounds will be necessary for satisfactory service. A pressure of at least 20 pounds is also needed to insure adequate supply of water to fire engines.

Considering the low service sytem, if a pressure of 25 pounds is to be maintained at Station No. 3, elevation 70 feet and distant about 32,000 feet from North Point, it will be necessary to limit the friction loss to a total of 10 pounds, or about 0.3 pounds per 1,000 feet, a value requiring lower velocities (0.5 to 2 feet per second) and larger pipes than is scarcely practicable. It is evident, therefore, that if the low service system is extended on the south side above elevation 65 or 70 feet, the pressures are likely to be unsatisfactory, and at more distant points a still lower elevation would be the limit.

In the high pressure system the pressures at Station No. 11 were very low, owing partly to the high elevation of this point (149 feet) and partly to the high friction loss (24 pounds). The normal static pressure here is only 32 pounds, and at Station No. 6 it is only 38 pounds. At Station No. 11 the loss is especially great by reason of the large amount of water supplied to the county buildings in Wauwatosa on this line of pipe. It may be said, however, that the friction loss in the high pressure system is generally too great, amounting in several cases to over 1 foot per 1,000 feet (corresponding to velocities of 2 to 4 feet per second), not considering the fire demand. This excessive loss is due to two causes: (1) the high velocity through the 36-inch pipe at the river crossing, giving a loss of as much as 1 pound per 1,000 feet when supplied entirely by the pumps at North Point; and (2) the relatively large areas which are fed from nothing larger than 8-inch pipes. This is particularly true of the high service area east of the 20-inch main on Eighth street, and the northern district in the Twentieth and Twenty-first wards. In the entire area east of Ninth street and north of Wright street (on which is located the new 36-inch main) the system consists of 6-inch pipes with 8-inch pipes at intervals of four to eight blocks. No 12-inch main crosses this entire district, although short sections of 12-inch pipe have been built. Similar conditions exist in the northwest section of the city. On the south side, in the low service district, the conditions have been the same, but the completion of the large mains on Lincoln avenue and Greenbush street will greatly improve conditions.

More liberal use of 12-inch sub-mains should be made in the gridiron system, placing these at intervals of four to six blocks in about the same manner in which the 8-inch pipes have previously been used. Such sub-mains appear to be especially needed at the present time at the extreme northern and southern ends of the system, and future extensions should provide generally for a closer spacing of such sub-mains.

It is probable that the method of paying for extensions by special assessment for the cost of a 6-inch pipe has influenced

to some extent the development of the system, but with the excellent financial condition of the Water department there should be ample funds available for mains fully adequate for satisfactory service in all districts. The normal static pressure in large areas of both the high and low service districts is comparatively low, and if the service is to be good the friction loss must be kept low by the use of mains of ample capacity.

It would also appear from the data here considered that the 70-foot contour is about the limit of elevation to which the low service system can be extended on the south side with satisfactory results. This gives a normal pressure of 37 pounds, and allows a friction loss of only 0.5 pounds per 1,000 feet to retain a working pressure of 20 pounds. In future extensions in this part of the city it should be carefully considered whether all elevations above 65 or 70 feet should not be placed in the high service district. In the high service area the normal static pressure is about 35 pounds at an elevation of 140 feet. At higher elevations the pressure is likely to be unsatisfactory under present conditions with respect to the force mains. Very little area in the city is above an elevation of 140 feet, but as the district west and north of Washington Park is developed, a somewhat higher pressure will have to be carried in the high service system than is now maintained.

RESERVOIR ON THE SOUTH SIDE

The low service system would be greatly strengthened by the construction of a small storage reservoir similar to that on the north side, at the extreme southern end of the city, located on ground of suitable elevation. Such reservoir would, during periods of maximum demand, feed the district from the south end, thus greatly reducing the friction loss and so maintaining much better pressures. It would thus, on the one hand, modify the requirements in the way of large mains in this district, or, on the other hand, increase the area which may be served by the low service system. It would add greatly to the safety and reliability of the system, and would also serve as a source of supply for any additional high service station that might in the

future be established in this region. The cost of such a reservoir would not be greater than a length of three or four miles of 36-inch mains. Such a reservoir, capable of supplying one-third of the maximum daily consumption on the south side, would effect a saving in friction loss of fully 10 pounds in the remote parts of the system, which is more than would be accomplished by an additional 36-inch main. This feature would be of great value and should receive careful consideration.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

1. That the average consumption per capita is likely to increase to some extent in the future, bringing the probable average daily consumption in 1920 to about 60,000,000 gallons, and in 1930 to about 80,000,000 gallons. The maximum hourly rate is about twice this average rate.

2. The future development of the city will be mainly in the high service district, so that the maximum rate of demand for the two districts will be approximately 60,000,000 gallons, each, in 1920, and from 75,000,000 to 90,000,000 gallons, each, in 1930, with the greater demand probably from the high service.

3. That by reason of inadequate capacity for future requirements, and for increased security against interruption of service, the construction of a new intake should be begun as soon as possible.

4. That the pumping capacity should be increased at once by replacing the old beam engines by one large unit, probably for the low service, and within the next four or five years by a second unit for the high service.

5. That further increase in pumping capacity should probably be provided in a second pumping station located west of the river and designed mainly for high service duty. Upon the completion of such a station the present high service station should be abandoned.

6. The principal feed mains on the south side are now fairly adequate, but should be supplanted in the near future by another large main crossing the river. The mains in this district must be of large size to maintain adequate pressures. A second feed main crossing the river to the high service district is imperatively needed and should be provided at once.

7. Pressures are too low at certain points, and indicate that the low pressure area on the south side has been extended to a somewhat higher elevation than is desirable. The pressure in the high pressure system is also too low in certain small areas.

8. The general system of pipes should be made somewhat more ample in the future by a more frequent use of 12-inch and 16-inch sub-mains.

9. That a second reservoir on the south side would add greatly to the safety and efficiency of the system, and to a greater degree than an equal expenditure for additional mains. Its construction should receive careful consideration.

PLATE I.

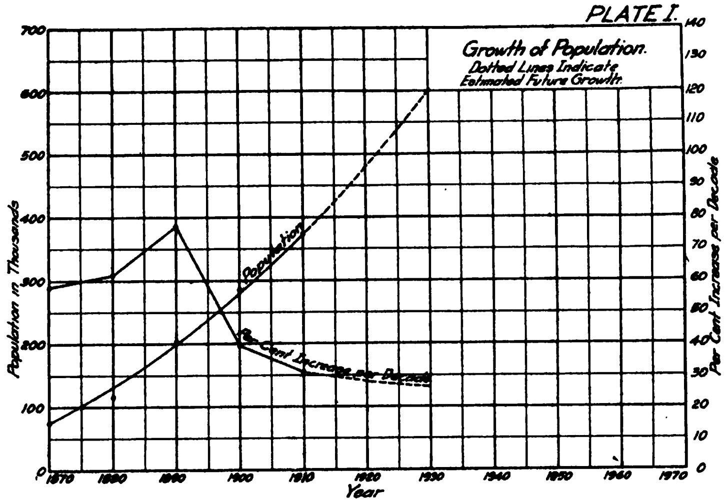


PLATE II.

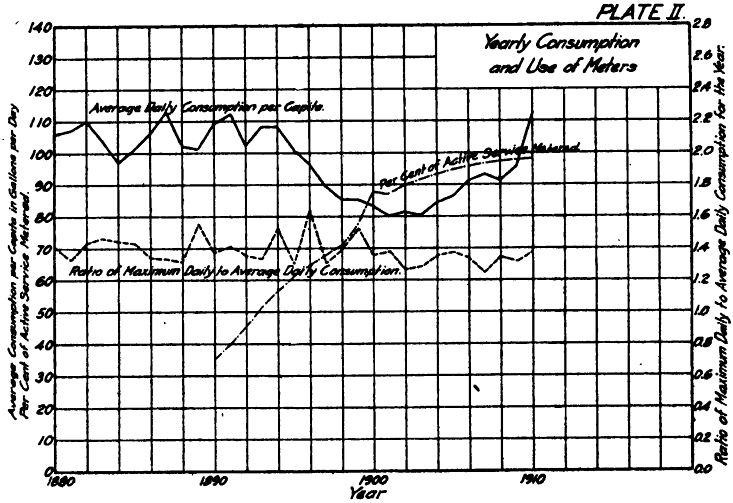
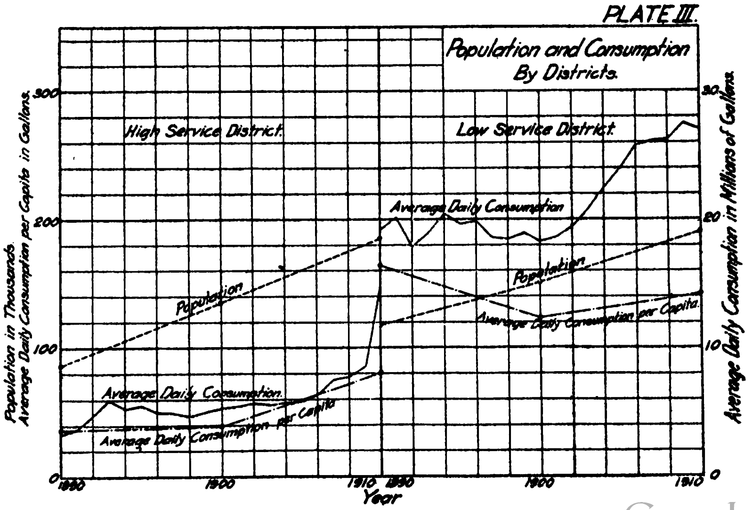


PLATE III.



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